Human Behavior Representation – Recent Developments

Andreas Tolk, Ph.D.
Virginia Modeling Analysis & Simulation Center (VMASC)
Old Dominion University
7000 College Drive, Suffolk VA 23435, USA
+1-757-686-6203
atolk@odu.edu

ABSTRACT

Until recently, the command and control processes and especially the decision process were - if at all - hard-coded in the closed combat simulation models. Although in other application areas expert systems and rule systems as well as neural nets were used to find solutions to similar problems, in the closed combat community these approaches are still not used sufficiently.

The problem with hard-coded decisions is always, that they are evaluated only for a special environment. Being transferred to another environment the decision model is seldom capable to meet the new requirements. Self-optimization and the skill to adapt to new situations are nowadays more often required by such systems.

This lecture introduces adjustable rule sets and neural networks as alternatives to generate orders in a given situation. The results and the possibilities for further improvement and evaluation of the results are given. In addition, some technical aspects of coupling the results in form of CGF federates with legacy systems and the challenge of structural variances are copied.

Further actual developments in the modeling of Human Behavior Representation come from Germany, where a new approach trying to catch the insight from latest psychology findings as well as modern agent technology are merged to a new solution of the well-known problems.

1 Introduction

This paper is divided into two parts.

In the first part, the recent findings regarding technology itself are introduced and compared. The technologies being introduced are neural networks and adjustable rule sets, already known from applications of expert systems.

The second part describes the actual findings of German study conducted on behalf of the German Ministry of Defense, Joint Staff. These works closely tied to respective NATO RTO activities as Germany has the leading for the ongoing LTSS on Human Behavior Representation, also being a topic of the underlying lecture series.

For additional information, respective points of contact are given at the end of this paper.

2 Technologies

Two techniques have been used to present knowledge that can be used to generate situation adequate orders for simulated units: rule systems of expert systems and neural nets. Both are typical representations of intelligent systems, however, both have advantages and disadvantages when choosing what is the right technique for an order generating instance within a closed combat simulation.

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The basic means have been developed during the dissertation [Tolk 1995] at the University of the Federal Armed Forces of Germany, Munich, and have been successfully applied within several research and industry projects, examples given in [Dompke & Tolk 1999, Tolk 1999a, Dompke 1999].

In this chapter, the terms adjustable rule sets and neural nets are defined in a way to understand the differences and potentials of both techniques. For exact definitions references to the respective literature are given.

This chapter is an extract from the article [Tolk 1999b], where more details and additional technical aspects are given.

2.1 Adjustable Rule Sets

Adjustable Rule Sets can be defined as a quadruple of input Parameters (x1, ..., xm), steering parameters (p1, ..., pj), a set of parametric rules (R1( ), ..., Ri( )), and output parameters (y1, ..., yn).

Dependent on the steering parameters the input parameters are matched to the output parameters by the rules within the rule set. Figure 1 shows this.

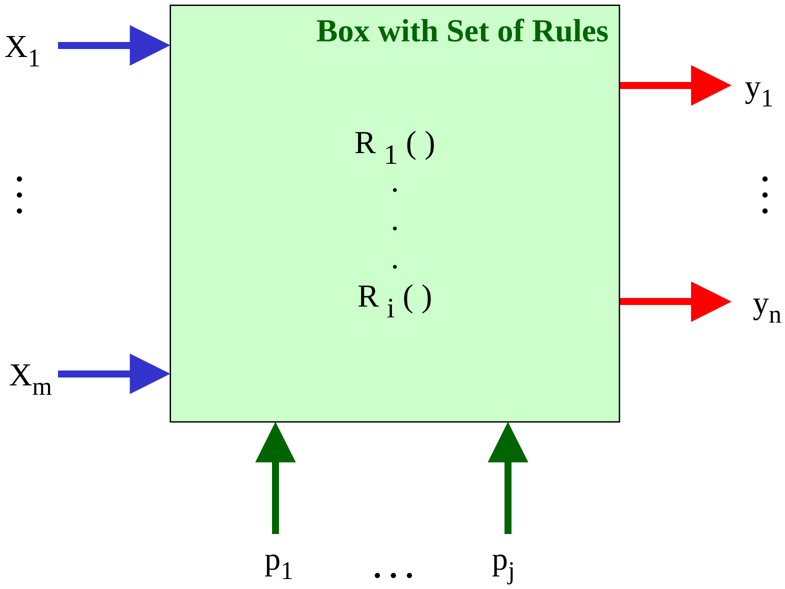

Figure 1: Adjustable Rule Sets

The internal rules can be seen as mathematical functions being as simple as possible or complex as necessary. They can range from simple addition algorithms over optimization algorithms to complex simulation functions being used for trend analyses on which e.g. the decision of other rules can be based on.

However, the rule set is limited and well defined. The steering parameters can be used as parameters within the functions being used by the rules, as parameters to choose which rules or sub-rule sets can be selected and so on. Therefore, the rules can be very flexible adapted by the steering parameters as long as the interior structure has been chosen adequate when building the adjustable rule set.

A more formal definition can be found in [Tolk 1995].

2.2 Neural Nets

Neural nets can be seen as a new way of computing by composing functions out of very easy and simple basic functions. These functions can be interconnected by their input and output parameters in a weighted manner similar to the neuron connections in the human brain.

Each neuron can be defined by its input parameters weighted by a synaptic value and the activity function transforming the synaptic sum to one output parameter. Connecting the output parameter with the input parameters of other neurons results in a neural net.

In this sense, a neural net can be defined as a triple of input Parameters (x1, ..., xm), synaptic weights (w1, ..., wj) that implicitly defines the topology of the net, and output parameters (y1, ..., yn).

Dependent on the synaptic weights the input parameters are matched to the output parameters, as can be seen in Figure 2.

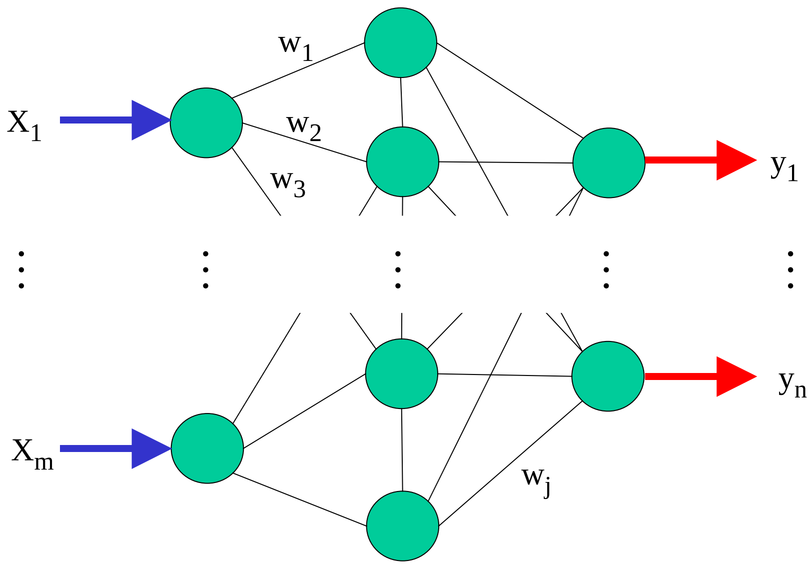

Figure 2: Neural Nets

Normally, the weights are set during the learning phase. When the net is used to match the input values to respective output values, all the information is hidden within the structure of the net and the actual chosen synaptic weights. Therefore, the weights are not steering parameters. However, the net can learn to use input parameters or hidden patterns in the input parameters as implicit steering parameters to be used within the net to decide what the correct output values are in such a case.

A more formal definition can be found in [Masters 1993] and uncountable other publications.

2.3 Comparison of Adjustable Rule Sets and Neural Nets

In general, the technique of adjustable rule sets belongs more to the family of deliberative – i.e. descriptive – CGF solution, whereas neural nets are more likely to be seen as reactive represents of CGF.

In order to compare both techniques, seven areas of interest are evaluated. The importance of each area for fulfilling a given task is the criterion for the decision which techniques can be used for a special purpose.

All seven sections describing each area comprise three parts. The first one describes the objective, the second the aspects of adjustable rules and the third the aspects of neural nets regarding the objective.

Approximation of a Function

The Objective is to approximate an implicit given function to arbitrary accuracy in order to use this function for the decision process.

- Every known function can be programmed as a rule within the adjustable rule set. However, having just an implicit given function assumptions have to be made. It is possible to introduce several alternatives that can be selected by respective steering parameter values.
- Neural nets can approximate every function to arbitrary accuracy, even if the function is subtle or deeply hidden within the patterns of the learning examples [Masters 1993]. No assumption – potentially unnecessary limiting the search area for the solution – has to be made.

Use in Similar Situations

The Objective is to get meaningful results when applying the techniques in areas having only a similar situation that do not match exact learning examples.

- In general, adaptive rule sets use standard rules for standard situations. The main problem is, therefore, to find the most similar standard situation. If a situation is to far away from all introduced standard situations, a new rule has to be created and programmed.
- Due to their ability to generalize a neural net can make a decision in every situation. If a given situation is within the domains of the training examples, the neural net can produce an adequate interpolation between all affected standard or training values. However, even if there is no relevant training data and the situation is completely new, the neural net will make a decision anyhow, without warning the user that the assumptions are not true for a given application.

Possibility of Adaptation

The Objective is to adapt the technique to a new situation with very little effort.

- If the adjustable rule set is flexible enough, i.e. if all necessary inner parameters can be set from outside by steering parameters, the rule set can be adapted to a new situation by choosing the right values for the steering parameters. In [Tolk 1995] this has been done for the rule set of a complex rule system of a closed combat simulation system on Corps/Division level. However, it may be necessary to introduce new rules for unforeseen situations.
- Using the techniques of reinforcement learning, a neural net can be adapted to every new situation. However, this process can be very time consuming. If in addition the net topology is suboptimal or even wrong, it is necessary to rebuild the neural net and to start from the beginning.

Possibility of Optimization

The objective is to optimize the technique in another situation rather than the foreseen one.

- By choosing the right steering parameter values, the behavior of adjustable rule sets can be dramatically improved. However, the number of inner functions and rules limits the solution space being reachable for a given set.
- As every function can be approximated sufficiently, each optimum can be reached. However, as in many cases means of heuristic optimization like genetic algorithms or simulated annealing have to be used, it is not sure that in every case the optimum is really found. In addition, the process can be very time consuming.

Extensibility

The objective is to extend the technique by the user for new situations.

- New rules can be added to the rule set at any time and existing rules can be modified. There are no limitations to this process.
- Extending a neural net means, that in cases the net topology has to be changed, and a new training phase is necessary. All the former work has to be done again. It is not possible for the user to add new information by analytical means.

Explainability

The objective is that a user can understand how a given decision has been made within the means of the underlying technique, i.e., how can the results be explained – at least in the retrospective – for the user?

- A rule set can be well understood due to the inner construction of human readable rules and functions. In addition, explaining components can be used being attached to the respective rules. When using expert systems, the user can be informed about all aspects all the time.
- This is impossible for neural nets. There are no explaining components for this technique. Even the evaluation of the synaptic weights and the topology of the net is of no benefit for the user. Neural nets “have to be believed”.

Effort of Construction

The last criterion focuses on the effort that is necessary to build an adjustable rule set or a neural net to generate orders and to be used as a CGF federate within a legacy simulation system.

- Before optimizing an adjustable rule set, as has been done in [Tolk 1995], the rule set has to be created and all rules have to be implemented at first. Although this can happen gradually and in an evolutionary software development process, this can take a tremendous amount of effort. In addition, respective experts are necessary to define the functions from the users point of view. On the other hand, having a given rule set that can be made adjustable by making all respective steering parameters public. Afterwards, genetic algorithms and other heuristic optimization techniques can be used to adapt or optimize the legacy rule set [Tolk 1995].
- In order to build and train a neural net, at least the input and output parameters must be known. In addition, the complexity of the problem must be known in order to define the topology of the net correctly. When choosing the right topology, all benefits of neural nets can be used. However, we are still missing an exact method to define an adequate topology. For non-trivial problems only heuristics can be used.

Summary of Comparison Results

The summarize the findings of this chapters it can be said, that both techniques – adjustable rule sets as well as neural nets – have their justification in different contexts. As a rule of thumb, adjustable rule sets are to be preferred if the Explainability of the results is the main objective, and neural nets are to be preferred if the finding of optimal solution is the main purpose. However, both methods are still in the domain of actual research and development.

2.4 Example of Applying Adjustable Rule Sets and Neural Nets for Optimization

The application shall be exemplified showing the research results having been conducted by the author at the University of the Federal Armed Forces of Germany, Neubiberg/Munich, during he was working on his Ph.D.-Thesis [Tolk 1995].

In 1991, Jim Dewar of RAND Corporation published the work of his team concerning chaos in closed combat system [Dewar et al. 1991]. He introduced a very simple combat model, mainly based on a Lanchester attrition model including reinforcement by reserve. The decision to introduce the respective reserve group was based on two rules. The first rule looked at the actual force ratio, the second at the actual own strength. The battle ends when passing given thresholds for force ratio or remaining strength, i.e., if the force ratio rises over a given value or if the remaining strength falls below a given percentage of the initial strength. The following figure shows the results of parametric variations of the initial strength of red and blue forces.

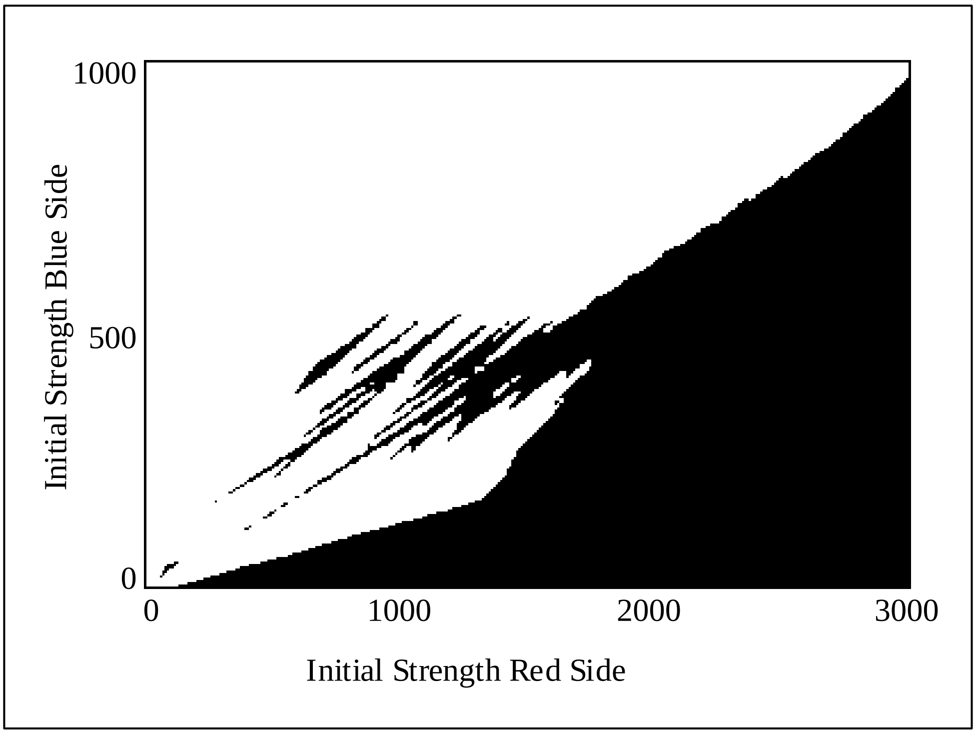

Figure 3: Simulation Results before Optimization [Dewar et al. 1991]

Within [Tolk 1995] it was shown, that the reason for the non-monotonicities was not chaos. The decision rules used were just not situation adequate, thus resulting in structural variances. Such variances do not occur only in closed simulation systems, but also in simulation federations, even when using validated and verified software modules, see [Tolk 1999a].

Using the optimization capabilities of adjustable rule sets as well as neural nets leads to interesting results. To do so, the decision rules were interpreted in the sense of adjustable rules on the one hand side, and on the other hand side, a neural net was trained to engage the reserve based on the actual perceived strengths as well as the initial strength of both sides. The following figure shows the results.

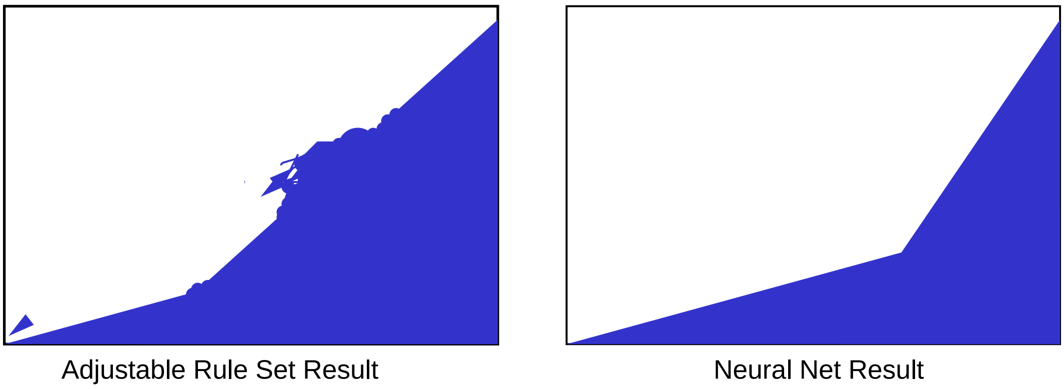

Figure 4: Simulation Results after Optimization

It is obvious that the neural net did the better optimization, however, it took a few days to understand what really happened and what the neural net did learn. On the other hand, the result of the optimized rules still could be improved, but the results could be understood at once without further evaluation.

3 Recent and Actual German Works

This chapter is based on a briefing having been given during the German-American Workshop on Command and Decision Modeling for Military Applications at Ft. Leavenworth, Kansas, by the German project manager for the study on Human Behavior Representation [von Bayer 2000].

The study itself is conducted on behalf of the Joint Staff of the German Ministry of Defense. To reach the study tasks, an interdisciplinary team approach was chosen. The team comprises human behavior experts and psychologists, military experts for command and control, peace support operations, etc., simulation experts and is open to other matter of subject experts in case of need. Beside the program manager Dr. Alexander von Bayer, two outstanding experts belonging to the team should be mentioned also: Prof. Dr. Kluwe from the University of the Federal Armed Forces at Hamburg, Germany, and Prof. Dr. Heineken from the University of Duisburg, Germany. In addition, officers from the MoD as well as from the Office for Exercises and Training are involved.

3.1 Study Tasks and Goals

The study task is to investigate, whether and how models of human behavior are needed for military simulation (analyses, computer assisted exercises, and support to operations) and how simulation technology itself has to be expanded in order to cover human behavior. Additionally to this more conceptual work, a prototypical demonstrator has to be developed. Last but not least the German national study is also used to sponsor the leadership within the respective NATO efforts.

It should be pointed out that the efforts should not lead to just adding a human component to legacy simulation systems, but the simulation of the socio-technical military system (single decision making, group decision process, perception of truth, individual and group behavior, influence of pressure, etc.) itself should undergo a rethinking process. From the NATO activities as well as from respective workshops and symposia it became already clear to the international simulation community, that human behavior representation becomes an application and research domain of its own.

Consequently, different from the well known US study efforts, the German study tries to focus on the answer to the question: What human behavior is relevant in military scenarios and how can this be modeled? In other words, the study and the prototype don’t try to model the human being itself but only the relevant human behavior in defined military situations. Starting with the NATO RTO definition: “Human behavior is a purposive reaction of a human being to a meaningful situation!” Germany is trying to define respective scenarios and vignettes to develop the prototype.

It was one of the main goals of the study team not to build up an own private psychology, but to base their efforts on accepted theoretical knowledge. In order to do so, the action regulation theory motivation concept as well as the ideas of natural decision making were evaluated and merged into a new approach being useful to describe real world phenomena, building an adequate theoretical concept, leading to respective mathematical models being able to be formatively validated gradually. One of the first main results is the Action Theory Based Model to be described in a little bit more detail in the following section.

3.2 The Action Theory Based Model

As already has been pointed out, the efforts are concentrated on those elements being directly understood in a military context, thus minimizing the necessary theoretical effort. In addition, model building and validation should go hand in hand whenever possible. Logically, the resulting Action Theory Based Model tries to visualize the inner processes of human behavior connecting given tasks and situations with respective outcomes. The following figure shows a simplifying view, however, the main ideas should become already clear.

Note that again, like in the ideas described earlier in these proceedings within the chapter “Computer Generated Forces - Integration into the Operational Environment”, we are using the concept of encapsulated functionality and well defined interfaces. For this black box of a behavior model, the inputs are defined as a given situation and the tasks to be performed, the output are the results. Therefore, an embedding simulation system can be used as a test bed.

Additionally, the steering or calibration parameters are used – the individual/personal characteristics as well as the team/group characteristics – to configure the model behavior like it is done for adjustable rule sets.

Overall, this allows us not only to design and implement behavior models in a modular and configurable manner, but we can also embed them into test beds or into the operational environment later using the integration techniques already described. Note that the interfaces again can be described using the standardized data elements of the NATO Standard Land C2 Information Exchange Data Model.

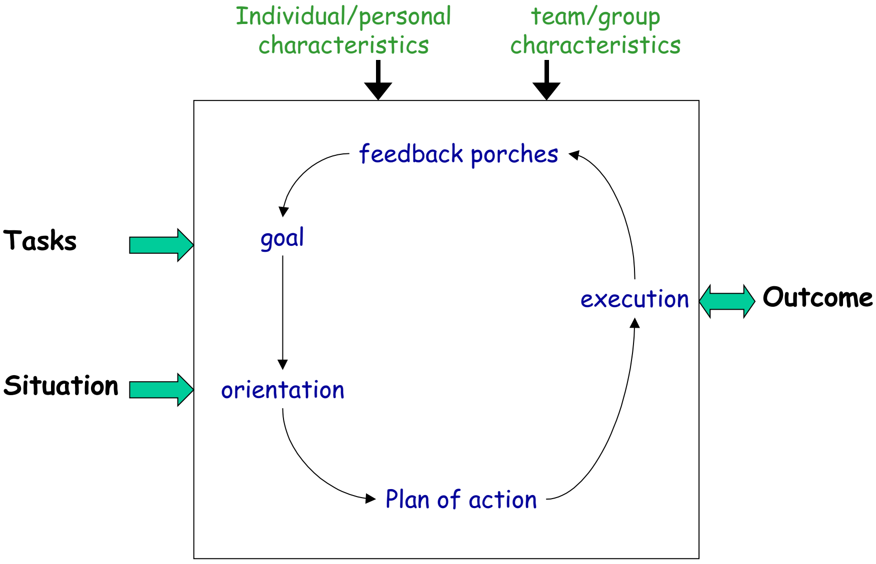

Figure 5: Behavior Process Model

This model allows to integrate and comprise cognitive processes (perception of the situation, recall of knowledge which is relevant to the recognized situation) as well as regulatory processes (causes of intentions, selection of intentions, change of intentions, etc.). Within the Action Theory Based Model therefore

- knowledge is activated and motives are triggered through situational elements
- intention is activated through anticipated goals and
- intention is executed using available (scripted) schemata at hand.

By introducing respective motives and schemata into the model, the parameters now can be set to model respective human behavior in given military situations. Motives themselves represent the human needs making the individual or group acting the way they are. Well-known motives are

- performance motive: accomplish what is ordered
- help motive: help people in need, irrespective of tasks
- might and imposition motive: imposing the own will
- social acceptance motive: doing what is assumed to be perceived to be done by others (or simply to be liked by others)
- personal security motive: personal security first
- aggression motive: wish to destroy and kill (e.g., for revenge or hate)

For the purpose of the study, only three schemata are scripted:

- “How to help” schema: Do whatever can be done to help
- “Task accomplishment” scheme: Task first, don’t deviate
- “How to delegate responsibilities” schema: Let other people decide (manager syndrome – never be in the same room as the decision), avoid responsibility

Motives as well as schemata are different in individual strength, thus being parametrical variables within the model itself.

Without going too much into details it should be mentioned, that this model has to be adapted to the three main behavior domains:

- Human Behavior Representation (behavior of individuals, i.e., prototypical soldiers and civil persons. However, it is not possible to model a real person, e.g., a real politician, to simulate the decision to be expected)
- Organizational Behavior Representation (behavior of organization, e.g., headquarters, command posts, governmental and non-governmental organizations, etc.)
- Mass Behavior Representation (behavior of large groups of people, e.g., demonstrations)

For all three domains, respective schemata – as defined above – can and have to be established. First works already proofed the feasibility of these efforts. In addition, it seems to be worth to think about a "warfighter like" presentation of the motives and schemas in their language and value system to make the results more understandable and easier to accept.

3.3 Application Areas

The German study started with human behavior representation for Computer Assisted Exercises, however, the application area is much larger. Anyhow, for the first steps, leadership training on all command levels with computer generated forces becomes possible. Training of commanders and their staff as "computer aided behavioral training" (e.g., for OOTW), the selection of leaders in realistic scenarios (OOTW assessment centers) etc. are additional features coming i9nto reachable distance (if wanted by the contractors).

4 Summary

To summarize this paper we seem to be on the edge of several breakthroughs. New technology and ongoing revolution in the information technique are leading towards new challenges and chances in the application domain of simulation of and for command and control.

NATO – and especially the Research and Technology Organization – has to step into its place not only to make the findings available to the nations, but also to harmonize and direct the different research efforts.

On the long term, the different domains of defense applications – be it simulation systems, command and control systems, human behavior representation, consultation, etc. – have to grow together, and this should take place under the leading umbrella of NATO.

5 Points of Contact

For further information on the neural network and adjustable rule set approach please contact the author of this paper.

For additional information including reports of progress feel free to contact the project leader:

Dr. Alexander von Bayer
IABG IK31
Einsteinstr. 20
85521 Ottobrunn
Germany
Email: baeyer@iabg.de

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Human Behavior Representation – Recent Developments

Dr. Andreas Tolk

IABG

Weapon System Analyses

Munich, Germany

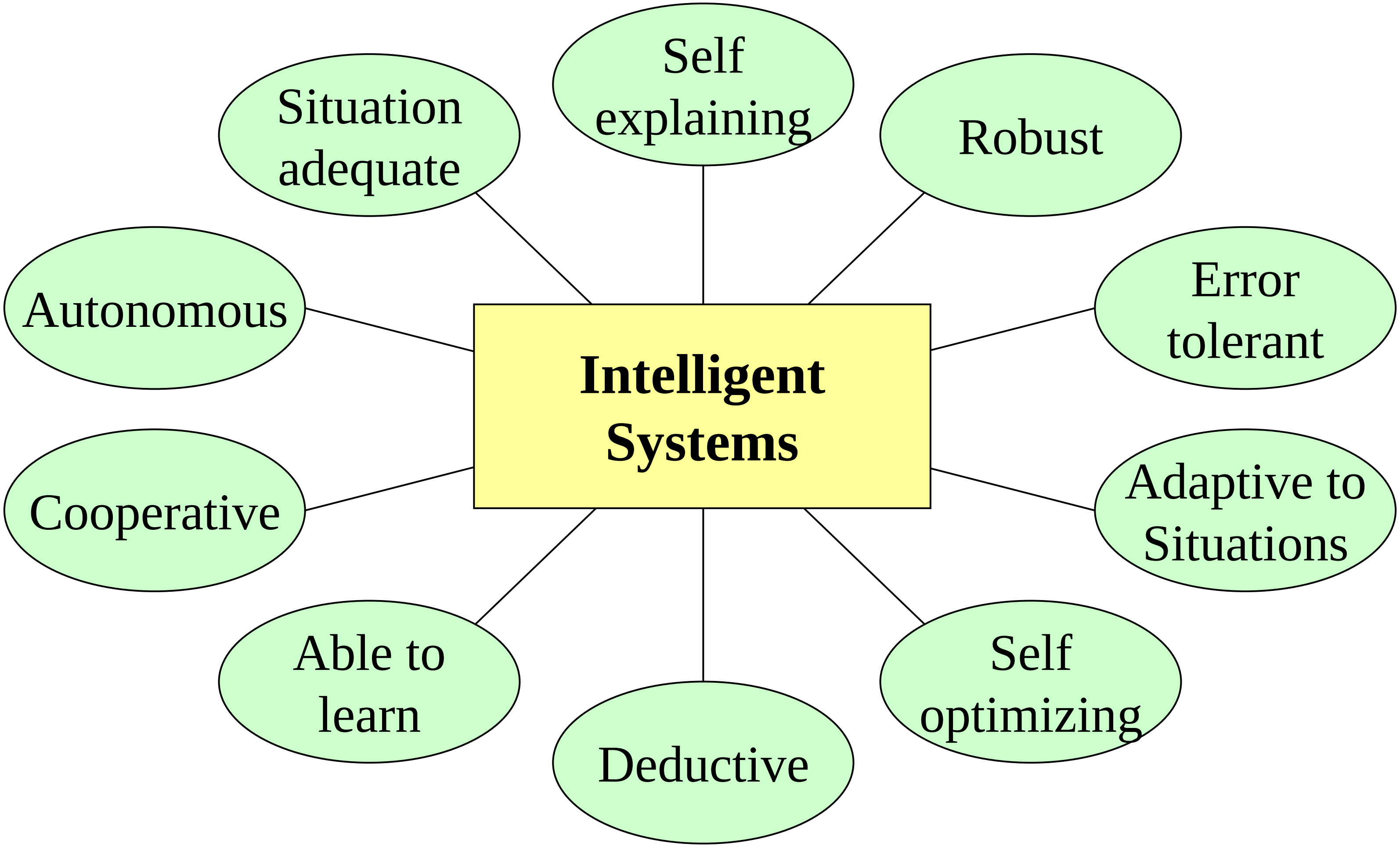
Structure of This Presentation

- Introduction
- Examples of Relevant Technologies
  - Neural Networks versus Adjustable Rule Sets
- Recent Developments
  - The Action-Theory-Based-Model
- Summary

Examples of Relevant Technologies

- Human Behavior is still Subject of Ongoing Research
- NATO Code of Best Practice for the Assessment of Command and Control (NATO SAS026)
  - Integration of Human and Social Science Findings
  - Integration of Psychological Models
  - Human, Organizational and Mass Behavior Models needed for Analysis and Training
- Technologies must be capable of meeting these Requirements
  - Adaptable to new Situations
  - Learning
  - Interpolation from Training Situation to Real Situation
- Technology must support „Intelligent Systems“

Intelligent Systems



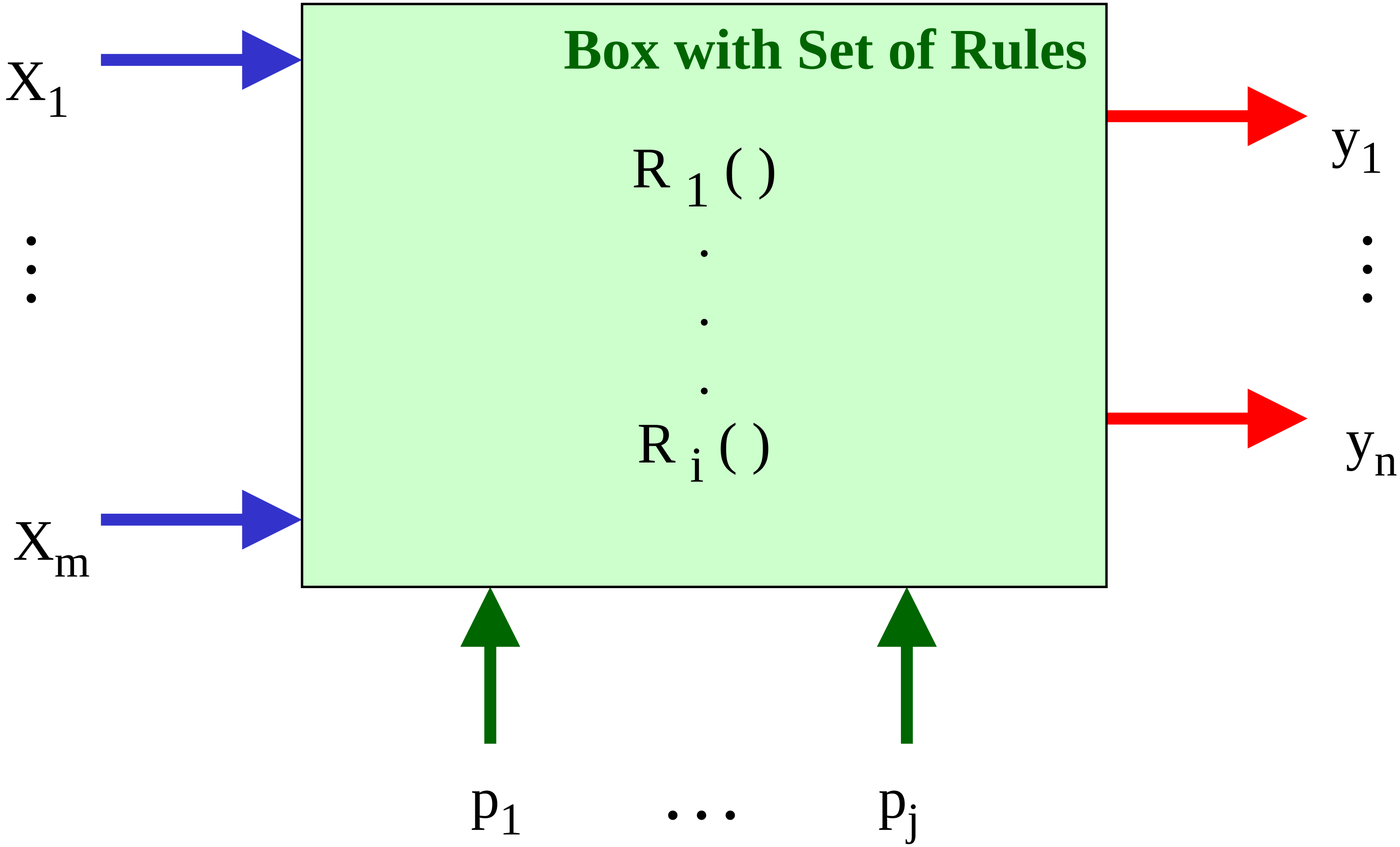
CGF and Intelligent Systems

- **CGF-Federates** or **CGF-Modules** must behave like Intelligent Systems:
  - Generate Situation Adequate Decisions
  - Adapt to new Situation
  - Self Optimizing
  - Cooperative
  - Self Explaining (How Decision was made)
  - . . .

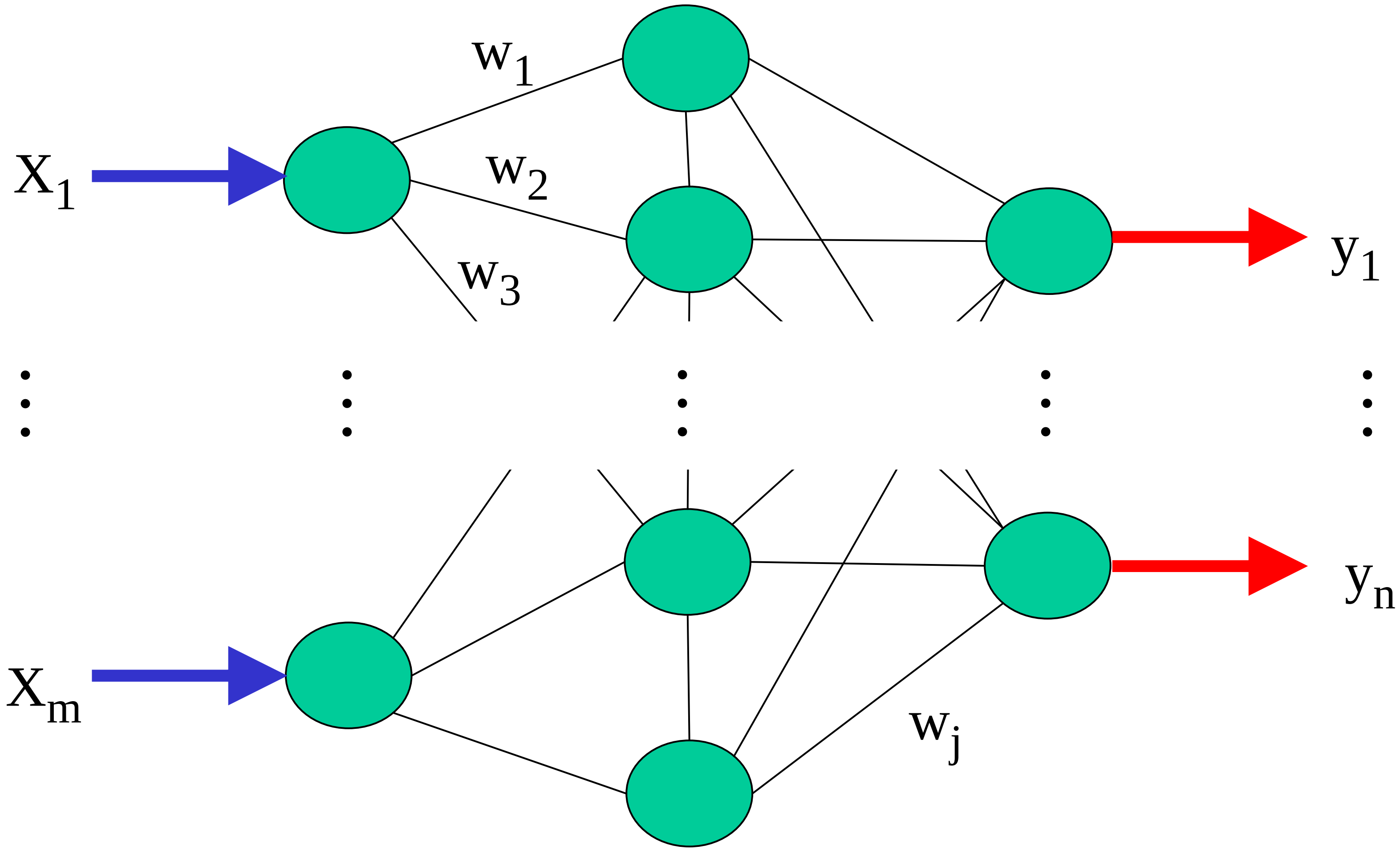
Adjustable Rule Sets and Neural Nets

- Adjustable Rule Sets
  - Set of Rules/Functions with Input Parameters, Output Parameters and Steering Parameters
- Neural Nets
  - Net of Neurons defined by Input Parameters, Topology, Synaptic Sum in each Neuron, Activity Function and Output Parameters

Adjustable Rule Sets



Neural Nets



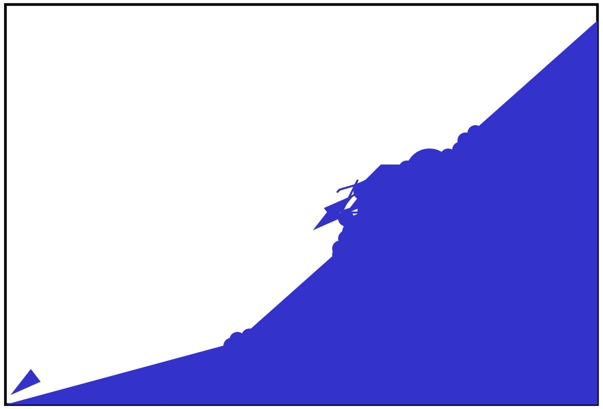
Example: Engagement of the Reserve

- Input parameters:
  - Initial strength own troops
  - Actual strength own troops
  - Perceived strength opponent forces
- Steering parameters:
  - Force ratio for engagement of the reserve
  - Actual strength threshold for engagement of the reserve
- Output parameter:
  - Order to engage the own reserve

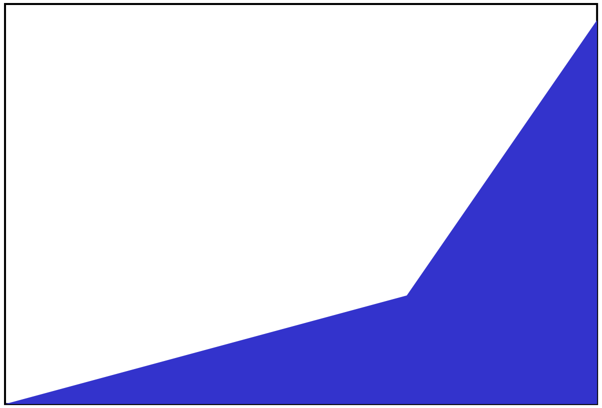
Comparison of the Optimization

Initial Rules:
Call Reserve:
Force Ratio > 4:1
Own Strength < 80%

Initial Situation



Reserve optimized by AR



Reserve optimized by NN

Comparison of Applicability of Adjustable Rule Sets (AR) and Neural Nets (NN)

Criteria	AR	NN
Approximation of a given Function	+	++
Usability in Similar Situations	+	++
Possibility for Adaptation	+/-	++
Possibility for Self Optimization	-	++
Extensibility by User	++	--
Explainability to the User	++	--
Effort of Construction	+/-	+

Findings of the Comparison

- Technologies are available to fulfill the requirements for Intelligent Systems
  - **Adjustable Rule Sets** are to be preferred, if the Explainability of the Results is important
  - **Neural Nets** are to preferred, if the Finding of Optimal Solutions is the main Purpose

Recent Developments

- Presentation derived from still ongoing German efforts (see POC in the Paper)
- Objective
  - Agent Based Modeling
  - Psychological Models
  - Adaptation to Military Domain
- Action Theory Based Model

Study Goals and Objectives

- Requirements Analysis
  - Necessity of Human Behavior Representation (HBR) within Military Simulation in all Domains (Training, Analyses, Support to Operations)
  - Necessity to expand Simulation Technology to fulfill the Requirements derived from HBR Modeling
- Prototypical Demonstrator
- Sponsor for German Lead of the NATO Long Term Scientific Study on Human Behavior Representation

Approach of the Study Team (1/2)

- Main Study Team Members
  - Dr. Alexander von Bayer, IABG, Germany
  - Prof. Dr. Kluwe, University of the Federal Armed Forces, Hamburg, Germany
  - Prof. Dr. Heineken, University of Duisburg, Germany

Human Behavior is more than the delaying factor in an otherwise technically optimal operation!

  - New Problem Awareness for Simulation Developers
  - Not just adding a „Human Component“ to existing Systems
  - Simulation of the socio-technical military system
- Based on accepted theoretical knowledge

Approach of the Study Team (2/2)

- NATO RTO Definition as a Starting Point

  „Human behavior is a purposive reaction of a human being to a meaningful situation!“

- Main Question to be answered

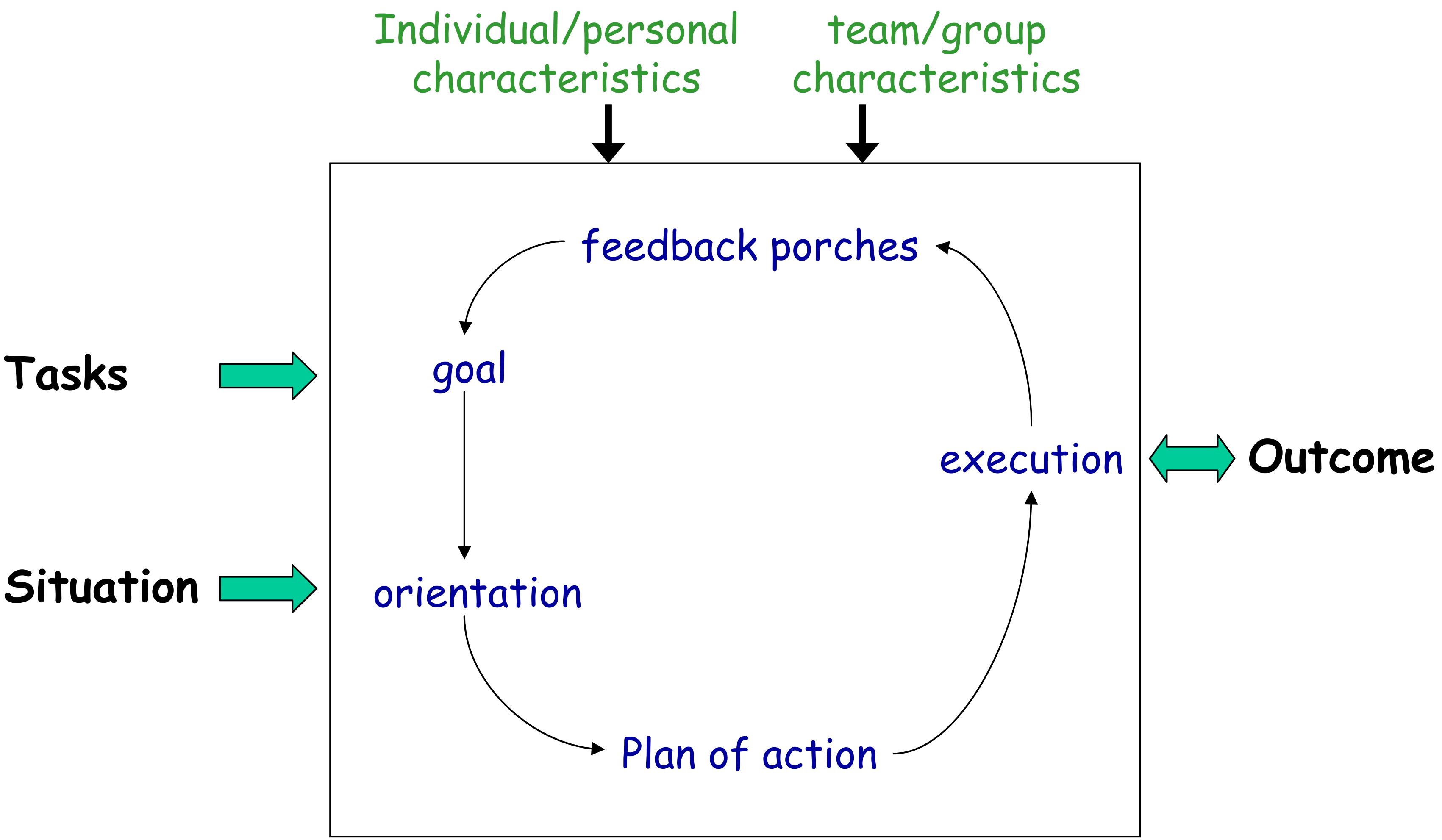
What Human Behavior is relevant in a Military Scenario?
How can this be modeled?

- Resulting Principle
  - Don‘t model the Human Being itself
  - Limit to the model of relevant Behavior within given meaningful military situations

The Action Theory Based Model

- Concentration on Elements directly understood in a military context
  - Connect Tasks with observed Outputs
  - Comparison of observed Outputs with desired Outputs
- Visualization of the Inner Human Behavior Process
- Use Motives and Schemata to model and explain Observations
- Derivation of a Behavior Process Model

The Behavior Process Model



Conceptual Motives and Schemata

Performance Motive:

accomplish what is ordered

Help Motive:

help people in need, irrespective of tasks

Might and Imposition Motive:

imposing the own will

Social Acceptance Motive:

doing what is assumed to be perceived to be done by others (or simply to be liked by others)

Personal Security Motive:

personal security first

Aggression Motive:

wish to destroy and kill (e.g., for revenge or hate)

Implemented Motives and Schemata

- Three Schemata are scripted:
  - "**How to help**" Schema:
    Do whatever can be done to help
  - "**Task accomplishment**" Schema:
    Task first, don't deviate
  - "**How to delegate responsibilities**" Schema:
    Let other people decide (manager syndrome – never be in the same room as the decision), avoid responsibility
- Motives as well as schemata are different in individual strength, thus being parametrical variables within the model itself.

Summary of first Findings

- Applicability proofed by Prototype
  - Limited to Computer Assisted Exercise (CAX) Domain
  - Limited to the three implemented Schemata
- Model must be adapted to
  - Individual Behavior
  - Organizational Behavior
  - Mass Behavior
- Re-Thinking Process for Military Modeling and Simulation is necessary

Summary

- We are in a Break-Through / Paradigm Shift
  - Integration Techniques are available
  - Psychological Models are applicable and adaptable
  - Integration into NATO Code of Best Practices is ongoing (e.g., NATO SAS026)
- Long Term Vision:
  Integration of
  - Command and Control
  - Modeling and Simulation
  - Human Behavior Representation / CGF

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